CORA Cork Open Research Archive
Cartlann Taighde Oscailte Chorcaí

Title	HAVE Experience: an investigation into VR empathy for panic disorder
Authors	Russell, Vincent;Barry, Rachel;Murphy, David
Publication date	2018-08
Original Citation	Russell, V., Barry, R. and Murphy, D. (2018) 'HAVE Experience: An Investigation into VR Empathy for Panic Disorder', 2018 IEEE Games, Entertainment, Media Conference (GEM), Galway, 15-17 August, pp. 167-172. doi: 10.1109/GEM.2018.8516461
Type of publication	Conference item
Link to publisher's version	https://ieeexplore.ieee.org/document/8516461 - 10.1109/GEM.2018.8516461
Rights	© 2018 IEEE. Personal use of this material is permitted. Permission from IEEE must be obtained for all other uses, in any current or future media, including reprinting/republishing this material for advertising or promotional purposes, creating new collective works, for resale or redistribution to servers or lists, or reuse of any copyrighted component of this work in other works.
Download date	2026-10-06 18:43:52
Item downloaded from	https://hdl.handle.net/10468/7197

UCC
University College Cork, Ireland
Coláiste na hOllscoile Corcaigh

HAVE Experience: An Investigation into VR Empathy for Panic Disorder

Vincent Russell
Department of Computer Science
University College Cork
Cork, Ireland
v.russell@cs.ucc.ie

Rachel Barry
Department of Computer Science
University College Cork
Cork, Ireland

David Murphy
Department of Computer Science
University College Cork
Cork, Ireland
d.murphy@cs.ucc.ie

***Abstract*— This paper presents a Virtual Reality (VR) system that was developed to increase empathy and understanding for panic disorder. The system is designed to give users a heightened awareness of the experience of those symptoms and a deeper, experiential understanding and empathy towards sufferers of panic attacks. VR provides an immersive and controllable experimental environment and serves as a safe dynamic test bed suitable for the study of this topic. The research uses the immersive auditory and visual modalities of VR as contributing factors for a positive empathetic experience, which may be used by medical professionals or those seeking a greater understanding of panic attack symptoms through first hand experience. The main goal is to assess whether the system is capable of imparting users with an enhanced level of understanding of panic attack symptoms leading to a greater sense of empathy. The paper describes the design and implementation of the 'HAVE Experience', and an initial experiment conducted with 26 subjects in a controlled environment. Participants were situated in a virtual elevator, where they were exposed to increasing levels of panic disorder symptoms in a controlled manner. The findings indicate that VR is a good medium for conveying empathetic experiences. Moreover the study revealed that an overwhelming majority of participants felt an increased level of empathy and understanding for panic attack sufferers.**

Keywords*— *virtual reality, experience, panic attacks, panic disorder, anxiety, empathy, realism, ambisonic audio, spatial sound.

I. INTRODUCTION

This paper outlines the development of a Virtual Reality (VR) system that creates an experience for users, which emulates a number of the main symptoms of a panic attack. The target demographic for the experience is non-sufferers of panic attacks with the goal of creating empathy. The HAVE ('Haptic', 'Audio', 'Visual' and 'Empathy') Experience system presents users with an experience grounded in reality. Panic attacks are something that many people struggle with on a regular basis, or at least have experienced at some point in their lives. They are frightening crescendos of physiological events that leave sufferers in a mental state of panic. The combination of VR with reconstructed symptoms of panic aims to create a visceral, emotional representation of such an experience. It is anticipated that the immersive system will impart a greater sense of compassion and understanding of what sufferers endure.

A. Panic Attacks

Panic, or anxiety, attacks can include physiological responses such as cardiorespiratory distress, dizziness-related symptoms and also a cognitive (psychological) component. Some forms of anxiety disorders can involve either occasional or frequent panic attacks and these include, but are not limited to, panic disorder (PD), generalised anxiety disorder (GAD), posttraumatic stress disorder (PTSD) and phobias such as claustrophobia, acrophobia, social phobia. As noted by Boswell *et al*. [1], heightened physiological arousal is a core component of panic attacks. In the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM 5), the American Psychiatric Association outlined thirteen symptoms of panic attacks that included, for example:

- Accelerated heart rate
- Sweating
- Trembling
- Nausea
- Dizziness
- Feelings of unreality (Derealization)
- Fear of losing control

Often, a panic attack will begin with a sudden and unexpected rise of terror and reach a crescendo of fear and autonomic symptoms [2], which is sometimes referred to as sensory overload can include visual irregularities [3] such as tunnel vision, blurred vision and sensitivity to light. The severity of panic attack symptoms usually does not reflect the actual situation.

B. Existing Systems

VR systems currently exist which act as an extension of Exposure Therapy (ET). Exposure Therapy is used as a clinical tool in conjunction with Cognitive Behavioural Therapy (CBT) in the treatment of patients with anxiety disorders. ET involves gradually exposing patients to factors that trigger anxiety, resulting in a systematic desensitization that leads to "new and more neutral memory structures that 'overrule' the old anxiety-provoking ones" [4]. The graduated nature of the exposure affords the patient an opportunity to learn to cope with

triggering environments by gaining control of their emotional and physical reactions. While this form of ET can be effective, it is not free of limitations such as significant time dedication (the therapist must accompany the patient outside the office) and potentially excessive costs e.g., if the patient has a phobia of flying, repeated exposure to airplane journeys may incur high costs.

Virtual Reality Exposure Therapy (VRET) has been presented as an alternative to ET treatments of anxiety disorders. Research has focused on the efficacy of VRET in treating anxiety disorders such as panic disorder, PTSD, acrophobia, claustrophobia, social phobia, fear of public speaking and fear of flying [4-7]. For example, the VRET application '*Virtual Iraq'* by Rizzo *et al*. [8] showed positive results in treating PTSD in returning veterans.

With specific regard to panic disorder, Interoceptive Exposure (IE), a form of in-vivo CBT exposure therapy, encourages patient desensitization to the symptoms of panic attacks by deliberately inducing those symptoms and subsequently conditioning the patient's response to such sensations. Virtual Reality Interoceptive Exposure (VRIE) systems act as a technological extension of IE therapy and substitute real sensory stimuli with digital representations. Botella *et al*. [9] presented a study on the efficacy of the use of VR in the treatment of panic disorder to "present bodily sensations, including audible rapid heartbeats and panting as well as visual effects, while the patients are immersed in various VR environments". A study by Pérez-Ara *et al*. [10] found that a similar level of treatment efficacy resulted from VRIE therapy when compared with the same program conducted in-vivo. While these systems adequately represent the physiological symptoms of panic (e.g. heartbeat, breathing), to the extent where patients can identify them as being sufficiently similar to their own real experiences, VRIE is still a relatively new area.

II. Experiment Design

A. The Symptoms

Panic attacks are symptomatically heterogeneous; the symptom profile of each individual is unique and the frequency or intensity of symptoms differs amongst panic disorder patients [11]. Consequently, creating one system that wholly represents a 'typical' panic attack would be difficult, because individual sufferers may experience varying degrees of each symptom during panic. Therefore, for the purposes of this work, the most commonly self-reported symptoms were focused upon. In their study of the panic attack symptomatology in 188 sufferers of anxiety disorder and panic attacks Cox *et al*. [4] note that particular DSM-III-R symptoms such as palpitations, tachycardia and dizziness were reported by almost all subjects and had the highest mean severity ratings. The subjects also widely reported feelings of unreality and auditory and visual disturbances.

The symptoms that were impossible to emulate in the system, which include internal cognitive and mental elements, were excluded from the design process. For instance, it would not have been possible to present feelings of helplessness, fear of losing control, and fear of dying in subjects, short of providing audio detailing such feelings. It was decided that merely presenting those thoughts as a script or voiceover would not have instilled those same feelings in the user, and would have distracted them from the impression that they themselves were experiencing from the symptoms. Whether these feelings would be induced within users via the presentation of the other symptoms would be determined only at the evaluation stage of the project.

It should be noted that this project does not aim to represent or to educate users upon the causes of anxiety attacks. Studies [11, 12] show that panic attacks can be caused by triggers associated with a variety of anxiety disorders, and that, regardless of the specific environments involved in triggering a panic attack, the reported symptoms correspond with those defined by American Psychiatric Association, with the presence and severity of various symptoms remaining specific to each individual sufferer. The design of the HAVE Experience system aims to represent as many of these symptoms as possible with the available VR technology.

B. The Virtual Environment

The virtual environment (VE) took the form of five different virtual worlds referred to henceforth as 'levels'. The first and fourth level acted as introduction (on-boarding) and completion (end-of-game) areas respectively. Levels one through three comprised of virtual elevators in the VE. The elevator metaphor was chosen as real-life elevators have been identified as environments that can trigger panic attacks due to their claustrophobic nature [6]. Additionally, all subjects taking the experience would have previously been inside an elevator and therefore the VE they encountered would have little or no learning curve.

The size of each virtual elevator was designed so that the user could physically walk around inside the elevator without exiting the physical 'play area'. It was deemed important that the movement inside the VE corresponded with the natural movement of the user. Freeman *et al*. [13] state that "perception through natural movement is the key element of an immersive VR system" and it was thus decided not to implement movement through the VE stemming from unnatural hand controller input.

C. The Modalities

The experiment targeted the senses of sight and hearing by including visual and spatial audio elements in the VE.

1) Visual

The crucial visual components of the project design included a high level of photorealism of the VE, and the visual effects (VFX), which would represent the visual irregularities, associated with panic attacks. These visual effects were designed to represent visual disturbances such as tunnel vision, blurred vision, and sensitivity to light. It was essential that the user felt 'present' in the VE, and it was believed that this sense of presence could be partially achieved by creating a high level of photorealism in the virtual world. It was deemed very important that users felt the textures of virtual objects were realistic and visually corresponded to their experiences of similar objects in the real world.

2) Audio

The audio system was designed to create a spatial auditory representation, or sound image, of the VE. As users would be able to walk around inside the VE it was thought that using a static, omnipresent audio source would have impaired the immersive quality of the experience. Thus, spatialization of the auditory elements was deemed to be a crucial factor in the creation of a credible VE. Introduced by Michael Gerzon in the 1970s [14], ambisonics is used to recreate the sound pressure field, which encapsulates the spatial cues of a real auditory scene. The combination of these spatial cues results in a 3D sound field within which the listener can localize sound sources [14]. While ambisonic audio can be played back over a multi-speaker setup, it was decided to render the ambisonics to binaural headphone output - to mirror the natural listening experience, which would increase users' sense of presence within the HAVE Experience.

D. The Voiceover

A voiceover was incorporated to condition and brief users on the nature of the virtual experience they were about to participate in. It included information on the virtual representation of the physical symptoms of anxiety attacks. Overall, the simulation does not include a high level of interactivity due to the nature of the topic; panic attacks are events that occur outside of the sufferer's control. Real-life panic attack sufferers do not have a significant level of control over their physiological symptoms, and it was deemed important to reflect this in the virtual experience. However, the user is free to end the experience at any time by pressing an 'exit' button, at which point they are played out of the experience in a measured and controlled way.

III. Implementation

A. Hardware

The HTC VIVE, which offers 2160 x 1200 combined pixel resolution at a refresh rate of 90 Hz and a 110˚ field of view (FOV), was the chosen VR head mounted display (HMD). The graphics card used was the NVIDIA GeForceTM GTX 970, a high-performance graphics card powered by NVIDIA® Maxwell™ architecture. The computer workstation had the Intel® Core™ i7-5820K Processor and 16GB of system RAM.

B. Software

Unity 3D, version 5.6.2f1, was chosen as the game development application for the experiment as it allows for native VR support, providing a base API feature set which is compatible with the HTC VIVE. To play Unity content on the HTC VIVE at runtime, STEAM, which includes STEAM®VR, was utilised. To create the models in the VE, the open-sourced modelling application Blender was used in conjunction with Substance Painter to produce the photorealistic textures.

C. Audio

The audio system built for the experience included both spatialized and non-spatialized audio [15, 16]. The spatialized audio took the form of First Order Ambisonics (FOA) which was recorded using the Sennheiser AMBEO® VR Mic which enables the spherical capture of sound arriving from all directions at a single point in space [17]. The audio sound fields of four different elevators, of varying size and ambient noise levels, were captured for the various levels in the experiment. Non-spatialized audio included the instructional voiceover and 'in-head' audio which was used to give the impression that the sounds were coming from the subject themselves and represented some of the auditory symptoms, including heartbeats, breathing and other auditory irregularities such as a high pitched noise played in the left ear, experienced during a real panic attack.

D. Visual Symptoms

Photorealism is important when creating a truly immersive environment and so a similar level of realism was desired for the visual disturbances in this experience. The visual effects were achieved using a mixture of animations and effects from the Unity Post Processing Stack. The Stack allows the application of filters to a camera's image buffer in a single post-processing pipeline. The effects implemented comprised of Bloom, Depth of Field, Chromatic Aberration and Grain, and emulated the symptoms of light sensitivity, blurry vision, tunnel vision and visual snow/irregularities respectively. The visual distortions were animated to change from a value of 0 to various intensities, and then return to 0. The stack construct is a powerful editing tool and it allows for the combination of several effects into a single pass.

E. Level Event Sequence

As panic attacks are in general, brief and often less than ten minutes in duration, it was decided to design the core experience so that the overall length of time is no longer than 10 minutes.

Level zero introduced users to the world of VR and conditioned them to the virtual environment. Calming ambient music, accompanied by neutral scene colours were used to induce a relaxed state in the user. Concurrently, a voiceover is presented, which outlines the simulated symptoms the user is about to experience and explains how to use the hand controller.

It was important to highlight the hand input controller to reinforce to the user that they could end the simulation if they wished by pressing the trackpad. In the event that the trackpad was pressed at any point in the experience, a 'take-down' process would be initialized. This resulted in all currently playing audio gradually reducing in volume to zero, and, similarly, the camera would transition to level four (the destination level).

After level zero, the view of the user would transition into a large lobby wherein they were facing the elevator doors from the outside. Ambisonic audio is played in the lobby area, which corresponds with certain events, such as the 'beep' from the call button, to signal that the elevator had arrived, and the elevator doors opening. The user would then step inside the elevator, with the doors closing behind them and the audio of the moving elevator would play. In this way the 'natural movement' aspect of the system's design was realised. Walking in the HAVE Experience is tightly integrated with the user's real movements; as noted by Freeman *et al*. [13], this natural movement is a crucial element of an immersive VR experience.

Levels two and three employed a number of effects and animations, introduced gradually and consistently, one after another to represent increasing stages of panic, as recommended by Witmer *et al*. [18]. Level two introduced some of the virtual symptoms and lasted for three minutes. Firstly, the user experiences a small level of tunnel vision accompanied by subtle auditory distortions. Gradually, the user becomes aware of an internalised heartbeat, the rate of which slowly increases, and audible shallow breathing is introduced. The elevator music begins to slow down with the onset of the auditory symptoms, and starts to sound slightly warped.

Level three employed a number of animations and ambient effects to create an unsettling atmosphere. This included a flickering light in the hallway and one in the elevator. At two minutes into the level, the walls of the elevator begin to shrink. This effect was intended to be a subtle acknowledgement of the feelings of helplessness and of being trapped that are often experienced in panic attacks. Level three includes the most severe visual disturbances, combining gradually increasing blurriness with tunnel vision and a static vision effect, similar to visual snow. A Non Player Character (NPC) is also introduced in the elevator (Fig. 1), further reducing the amount of perceived space the user can occupy. At this point all of the symptoms culminate in a representation of a full panic attack.

At five minutes into the level the auditory and visual virtual symptoms gradually revert to normal, with the elevator returning to its original size. The complete duration of level three is six minutes. At the end of the level, the camera transitions to level four.

Fig. 1: The Non Player Character (NPC)

Level four takes the user back to a calming world similar to level one, which would feel familiar to the user. A voiceover message is played to thank the user for participating in the experience and to let them know they can remove the headset.

It should be noted that only in levels one and four, the virtual model of the hand controller is visible, otherwise a seemingly 'floating' virtual hand controller would remind the user that they were in fact in a virtual environment. The controller was still active and functional, but the virtual model was not rendered. A decision was also made not to give the user an avatar to represent their virtual body (VB) in all levels. As stated by M. Slater, M. Usoh, and A. Steed [19], the participant's VB "should be similar in appearance to the participant's own body, respond correctly, and be seen to correlate with the movements of the participant" in order for the user to achieve a sufficient level of presence. Without specialised motion tracking suits available to control the movement of a VB, and multiple users in the test group, it was decided to forego this feature.

IV. Testing and Evaluation

A. Testing Protocol

Testing took place over the course of three separate days in controlled laboratory conditions, resulting in a sample size of n=26. The percentage of participants who had no previous experience using VR was 54%, and the average age of participants was 25.

Upon beginning the experience, participants stood in front of a marker on the floor ('X'), which represented the user's position outside of the virtual elevator doors in level one. When the virtual doors opened, participants were free to walk inside the elevator and to remain in that position until the end of the experience. Participants were also informed that they could end the simulation at any point; this information was reiterated via the voiceover in the landing level.

On completion of the experiment users were asked to fill out a survey, which was designed to evaluate the users' experience. This survey included both general demographic questions (age, education, occupation, level of VR experience) and those relating to the their experience of the experiment. The survey was aimed at evaluating the participants' sense of presence in the VE, the effectiveness of the audio and visual elements, the comfort of the hardware, the user experience, and ultimately if they gained understanding of, and empathy towards, panic attack sufferers as a result of taking the experience. Questions were reconfigured into statements for the purposes of using a Likert scale. A 5-point Likert scale on each statement was used to gauge the strength of participants' reactions to the experience.

B. Results

For this pilot study standard descriptive statistics were employed. The results were calculated using a weighted mean by assigning a weight (from 1 for strongly disagree to 5 for strongly agree) to each of the aggregated values across each point of the Likert scale, which were then summed and divided by n (the number of responses). The weights, calculated for each of the statements, gave a strong indicative response from the participants as a whole.

1) User Experience

Although some participants found the HMD and associated equipment uncomfortable, the findings were largely positive. Users strongly agreed they knew that they could end the experiment safely but did not want the experience to end prematurely, and the majority (77%) of participants found the length of the experience to be appropriate. However, it was less clear if users felt disoriented by the visual effects. While most

(50%) were not disoriented, a significant number were either neutral (23.1%) or agreed (26.9%) that they were (Fig. 2).

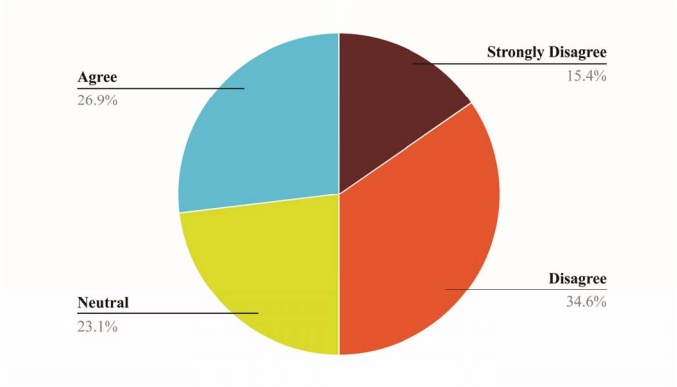

Fig. 2: Survey Statement: The visual effects made me disoriented.

2) Auditory Experience

Participants reported positive effectiveness at audio localisation, with all participants describing the audio localisation as 'Good' (38%) or 'Excellent' (62%). The majority (80.8%) of participants agreed that they could localize sounds in the virtual environment (Fig. 3). This confirmed that the use of ambisonic audio was effective in localising sources in an immersive environment [20].

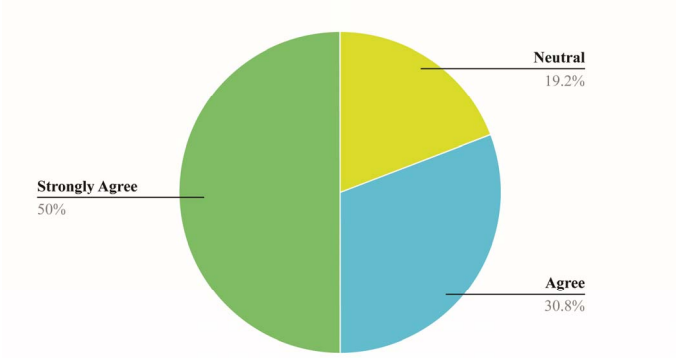

Fig. 3: Survey Statement: I could localize sounds in the environment.

3) Presence Experience

The majority of users felt a sense of presence during the experiment and agreed (88.4%) they felt 'present' in the elevator; less aware of their locale; less aware of external events; and lost track of time during their involvement [21, 22]. All participants agreed that the visual effects were realistic while 96.2% thought the virtual environment was convincing.

4) Empathetic Experience

As to the question of empathy and understanding, a majority (88.5%) reported that they would have an increased level of empathy and understanding for panic attack sufferers after taking the experience (Fig. 4). For each statement, users agreed, or strongly agreed, that they had gained sensitivity to the sufferers of anxiety. The mean weighted response (3.7) that users felt anxiety symptoms first-hand within the virtual experience was a primary objective of the study. Furthermore, the majority of users said they would have a greater understanding of and empathy for a person having an anxiety attack. It is argued that the strong sense of presence and positive user experience reported combined to produce a persuasive sense of empathy.

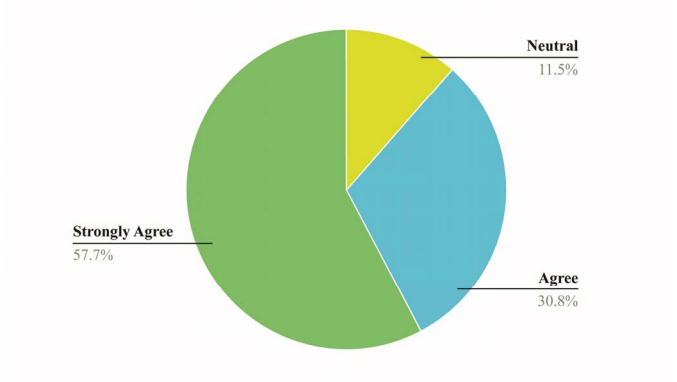

Fig. 4: Survey Statement: I would have greater empathy towards someone having a panic attack.

V. Conclusion

The primary objective of this study was to investigate the feasibility of using VR to develop an understanding of panic attacks, and to engender empathy for sufferers of the condition.

Due to the strong, positive response from this pilot study, it could be argued that this objective was achieved. It is believed that the immersive qualities of the system and strong user experience combined to produce a persuasive sense of empathy in those who participated.

An important finding of the experiment is that the majority of participants had developed an increased level of empathy, understanding and sensitivity for panic attack sufferers after undergoing the experience. Users reported feeling anxiety symptoms first-hand within the virtual experience - a primary goal of the study. Also of note were the responses that users would have a greater understanding of, and empathy for, a person having an anxiety attack.

The next phase of the research will incorporate haptic elements in to the VE. It is hypothesised that the inclusion of haptics will increase the realism of the experience and further increase the level of immersion. The haptic feedback would simulate the sensation of vibration as the elevator moves during the experience. The vibrations would be generated by low-frequency emitted from a vibrotactile display installed under the floor position marked 'X' upon which the user would stand for the duration of the experience. Additionally, more sophisticated statistical methods will be applied to establish relationships, and any correlations, between the different variables of the experiment.

ACKNOWLEDGMENT

The authors wish to thank University College Cork's CACSSS for their financial support, through the Postgraduate Research Travel Bursary, for the publication of this paper.

REFERENCES

[1] J. F. Boswell, T. J. Farchione, S. Sauer-Zavala, H. W. Murray, M. R. Fortune, and D. H. Barlow, 'Anxiety Sensitivity and Interoceptive Exposure: A Transdiagnostic Construct and Change Strategy', *Behavior therapy*, vol. 44, no. 3, pp. 417–431, 2013.

[2] D. F. Klein and H. M. Klein, 'The Status of Panic Disorder', *Curr Opin Psychiatry*, vol. 1, no. 2, pp. 177–83, 1988.

[3] B. J. Cox, R. P. Swinson, N. S. Endler, and G. R. Norton, 'The Symptom Structure of Panic Attacks', *Comprehensive Psychiatry*, vol. 35, no. 5, pp. 349–353, 1994.

[4] M. Krijn, P. M. Emmelkamp, R. P. Olafsson, and R. Biemond, 'Virtual Reality Exposure Therapy of Anxiety Disorders: A Review', *Clinical psychology review*, vol. 24, no. 3, pp. 259–281, 2004.

[5] K. Meyerbröker and P. M. Emmelkamp, 'Virtual Reality Exposure Therapy in Anxiety Disorders: A Systematic Review of Process-and-Outcome Studies', *Depression and anxiety*, vol. 27, no. 10, pp. 933–944, 2010.

[6] M. B. Powers and P. M. Emmelkamp, 'Virtual Reality Exposure Therapy for Anxiety Disorders: A Meta-Analysis', *Journal of anxiety disorders*, vol. 22, no. 3, pp. 561–569, 2008.

[7] B. K. Wiederhold and M. D. Wiederhold, *Virtual Reality Therapy for Anxiety Disorders: Advances in Evaluation and Treatment*. American Psychological Association, 2005.

[8] A. A. Rizzo *et al.*, 'Virtual Iraq: Initial Case Reports from a VR Exposure Therapy Application for Combat-Related Post Traumatic Stress Disorder', in *Virtual Rehabilitation, 2007*, 2007, pp. 124–130.

[9] C. Botella *et al.*, 'Virtual Reality Exposure in the Treatment of Panic Disorder and Agoraphobia: A Controlled Study', *Clinical Psychology & Psychotherapy*, vol. 14, no. 3, pp. 164–175, 2007.

[10] M. A. Pérez-Ara *et al.*, 'Virtual Reality Interoceptive Exposure for the Treatment of Panic Disorder and Agoraphobia'.

[11] N. B. Schmidt and J. Trakowski, 'Interoceptive Assessment and Exposure in Panic Disorder: A Descriptive Study', *Cognitive and Behavioral Practice*, vol. 11, no. 1, pp. 81–92, 2004.

[12] L. J. Dixon, J. J. Kemp, N. R. Farrell, S. M. Blakey, and B. J. Deacon, 'Interoceptive Exposure Exercises for Social Anxiety', *Journal of anxiety disorders*, vol. 33, pp. 25–34, 2015.

[13] D. Freeman *et al.*, 'Virtual Reality in the Assessment, Understanding, and Treatment of Mental Health Disorders', *Psychological medicine*, vol. 47, no. 14, pp. 2393–2400, 2017.

[14] D. G. Malham and A. Myatt, '3-D Sound Spatialization Using Ambisonic Techniques', *Computer music journal*, vol. 19, no. 4, pp. 58–70, 1995.

[15] B. Gallagher, 'Designing Immersive Sound for Virtual Reality', Hochschule für Angewandte Wissenschaften Hamburg.

[16] D. Murphy and F. Neff, 'Spatial Sound for Computer Games and Virtual Reality', *Game sound technology and player interaction: Concepts and developments*, pp. 287–312, 2010.

[17] F. Adriaensen, 'A Tetrahedral Microphone Processor for Ambisonic Recording', in *Proc. of the 5th Int. Linux Audio Conference (LAC07), Berlin, Germany*, 2007, pp. 64–69.

[18] B. G. Witmer and M. J. Singer, 'Measuring Presence in Virtual Environments: A Presence Questionnaire', *Presence*, vol. 7, no. 3, pp. 225–240, 1998.

[19] M. Slater, M. Usoh, and A. Steed, 'Depth of Presence in Virtual Environments', *Presence: Teleoperators & Virtual Environments*, vol. 3, no. 2, pp. 130–144, 1994.

[20] C. Jennett *et al.*, 'Measuring and Defining the Experience of Immersion in Games', *International journal of human-computer studies*, vol. 66, no. 9, pp. 641–661, 2008.

[21] C. Heeter, 'Being There: The Subjective Experience of Presence', *Presence: Teleoperators & Virtual Environments*, vol. 1, no. 2, pp. 262–271, 1992.

[22] J. Van Baren and W. IJsselsteijn, 'Measuring Presence: A Guide to Current Measurement Approaches', *Deliverable of the OmniPres project IST-2001-39237*, 2004.